Bridging the Gap: R&D to Help RPS Succeed

APS Views on Bringing Solar to the Utility Market

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Vision Statement

- Develop new renewable energy resources that will power our economy

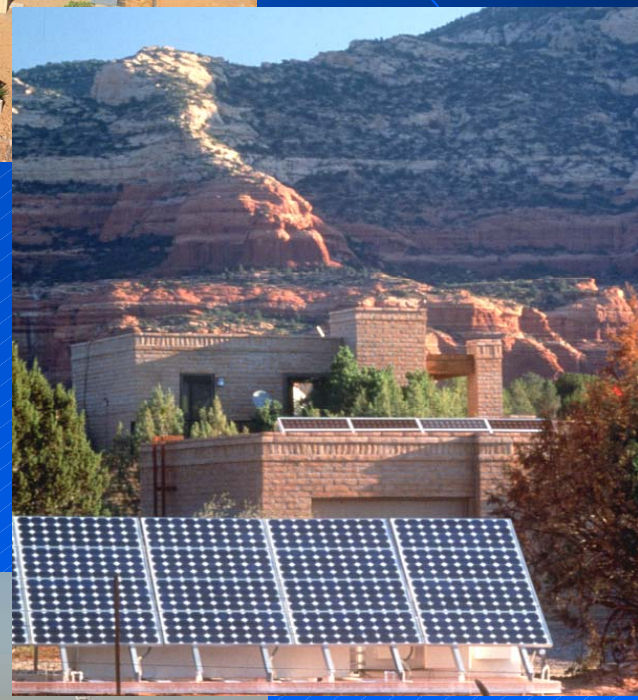
Goals and Objectives

- Good for the economy
- Better for the environment
- Affordable, reliable, convenient, accepted

Solar has tremendous potential for Arizona, but requires significant cost reductions and improvements before it will reach its potential as a substantial energy resource.

Rooftop PV, and Solar Power Plants

APS Solar Services



- Provide energy service, rather than sell equipment
- includes on-grid and off-grid, but large systems have more impact
- use what is here and now, while supporting improvements in technology

Assessing Value

- Look to wise-use of resources
  - much less use of carbon, CO2, and water
  - maximize energy delivered from materials used
- Look to market considerations
  - load following, system reliability
  - customer and market behaviors
  - existing industry, infrastructure
  - political and R&D funding -- and possibilities

Development Strategy

- Identify the most promising concepts
- Achieve near-term results that move us toward an economical solution
- Employ a pay-as-you-go approach -- avoid "stranded investments" as technology and markets change

Solar technologies most likely to rapidly grow to a substantial scale are those:

- with low cost at an early, moderate scale
- with higher system "load following" value

Present APS Uses of Solar

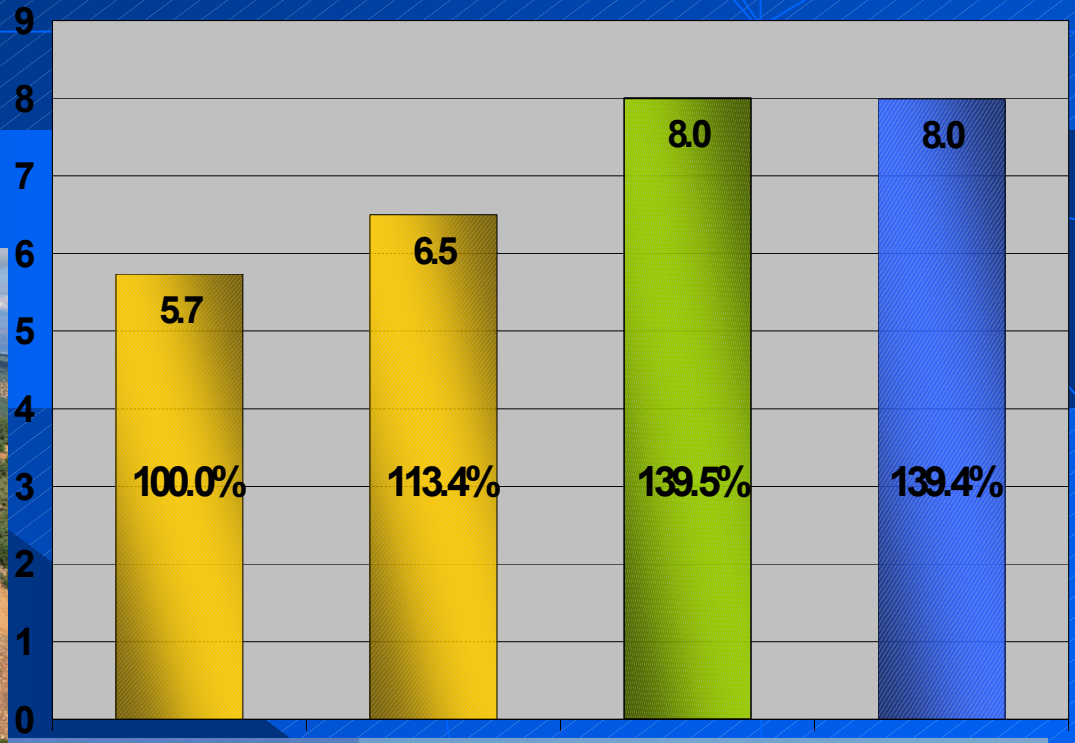
- PV hybrid services
  - US Army, San Juanico Mexico, Dangling Rope Marina, Natural Bridges National Park, Gray Wolf Landfill, 50+ remote residences -- 1 to 150 kW
- PV rooftops, primarily in showcase applications
  - schools, offices and customer sites
- Larger systems, using sun tracking for higher output
  - Flagstaff, Glendale, Gilbert, Scottsdale, Prescott, Tempe -- 100 kW to multi-megawatt

Toward Larger Scale Use of Solar

- Rooftop PV
  - most popular to some, but limited in system potential
  - no inherent storage or backup for load following
  - requires customer involvement, added liability
- Utility service
  - economies of scale, maintenance, optimization
  - solar thermal can load follow with storage, gas backup
  - is nicely NIMBY --

    most customers want to just “flip the switch”

Benefits of Solar Tracking



APS Technology Program

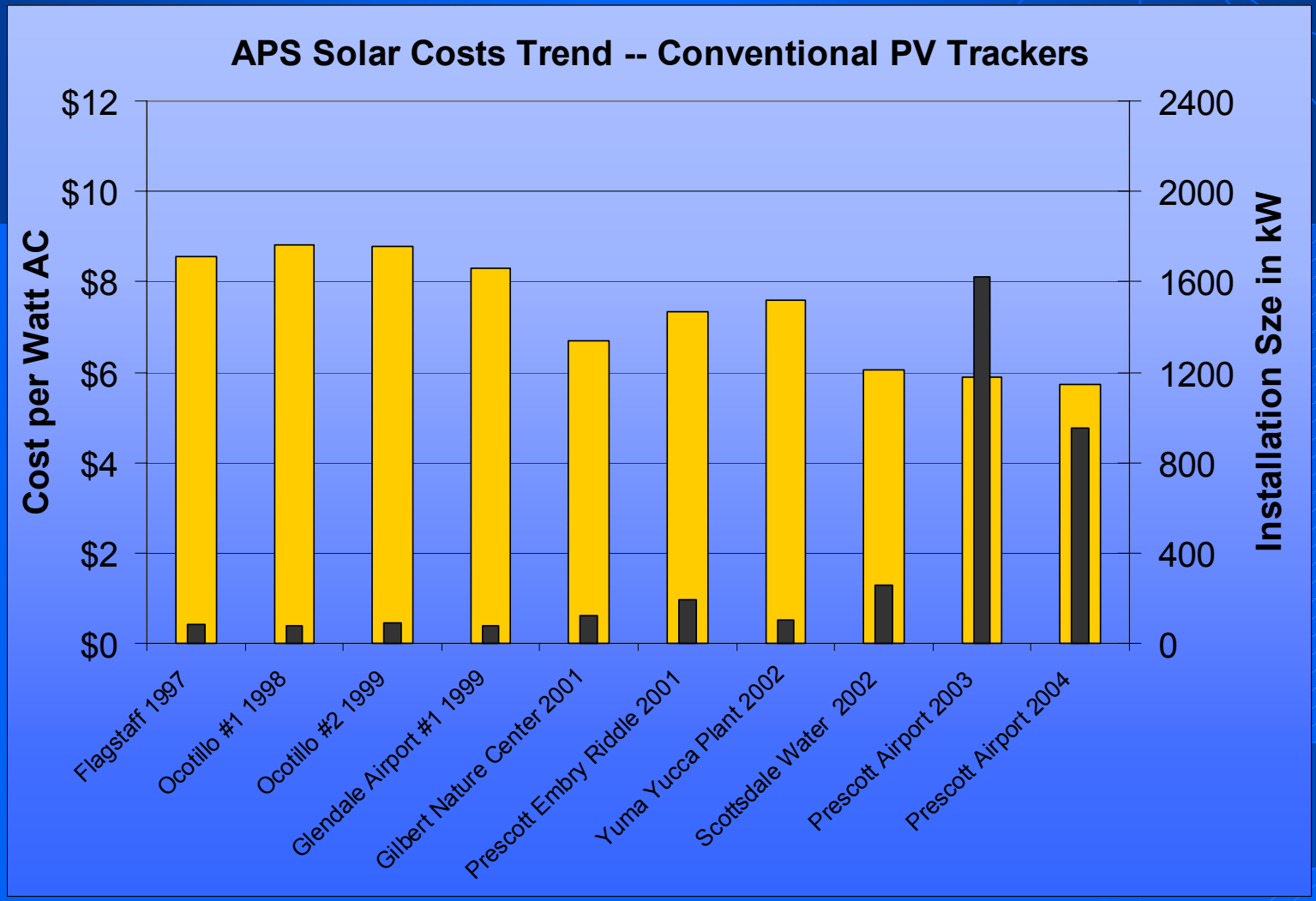
- Find more value to encourage greater use
  - serve off-grid needs when possible
  - increase output by tracking
  - add system value with storage or fuel
- Find ways to reduce costs
  - large solar trough plant & PV manufacturing was considered, but not pursued -- low payoff for very large cost
  - evaluate new ideas and products at APS STAR facility
  - work with technology developers, universities, national labs

Encourage the development of concentrating solar

- CPV and Dish Engine can be low cost at moderate scale
- both benefit from advancements in sun tracking

Examples of Technical Applications

APS PV Trackers -- System Cost Trends

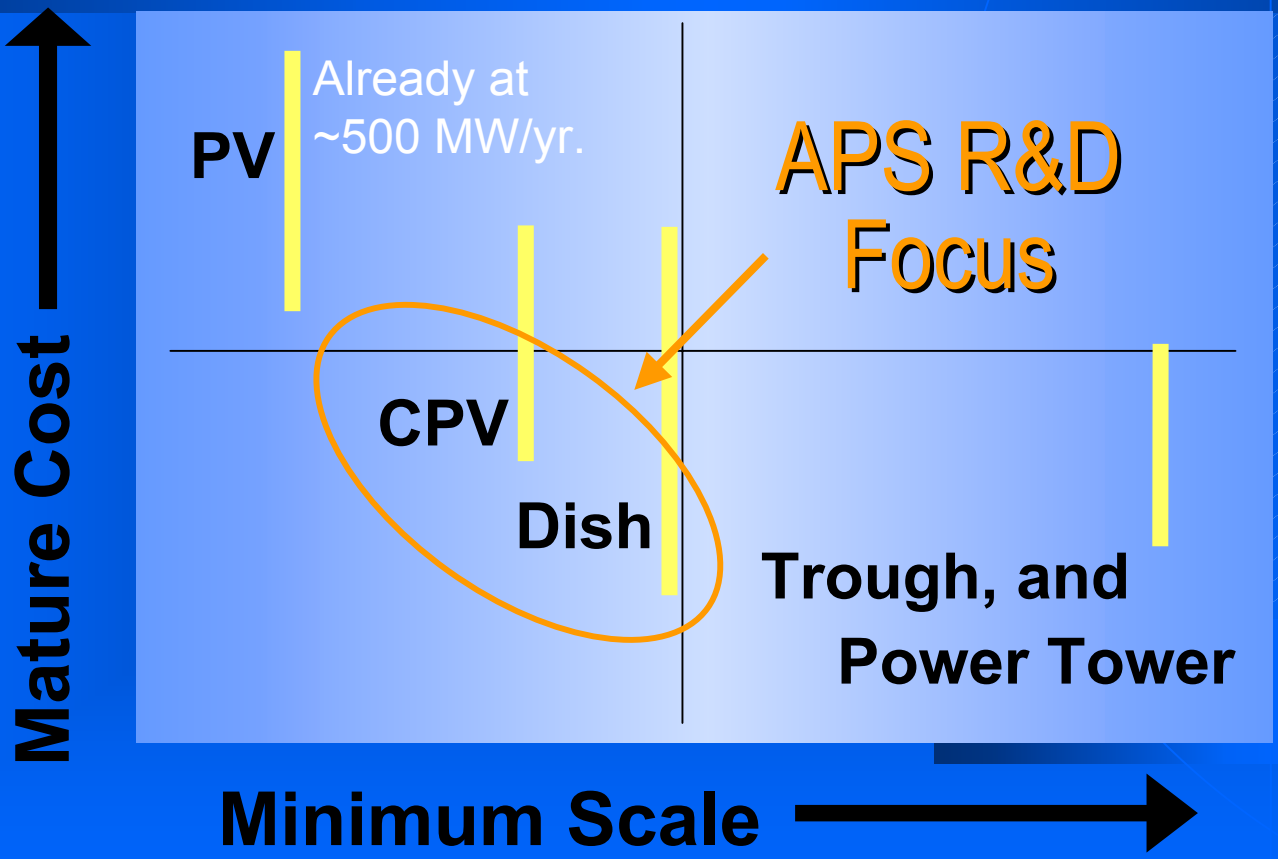


Emerging Solar -- Focus Areas

- High Concentration PV
  - 500 kW now being demonstrated in field
    - reliable silicon cell, today's workhorse at 26% cell efficiency
  - looking to multi-junction space cells to increase efficiency
    - 30% cells, with up to 40% under development
- Solar thermal electric
  - constructing 1 MW solar trough plant
    - to make modular version of ~80 MW technology
  - supporting Dish, with particular interest in turbine engines

Examples of Modular-Scale Solar Concentrators

Potential Cost and Size Attributes



Only flat-PV technologies are currently being installed in volume.

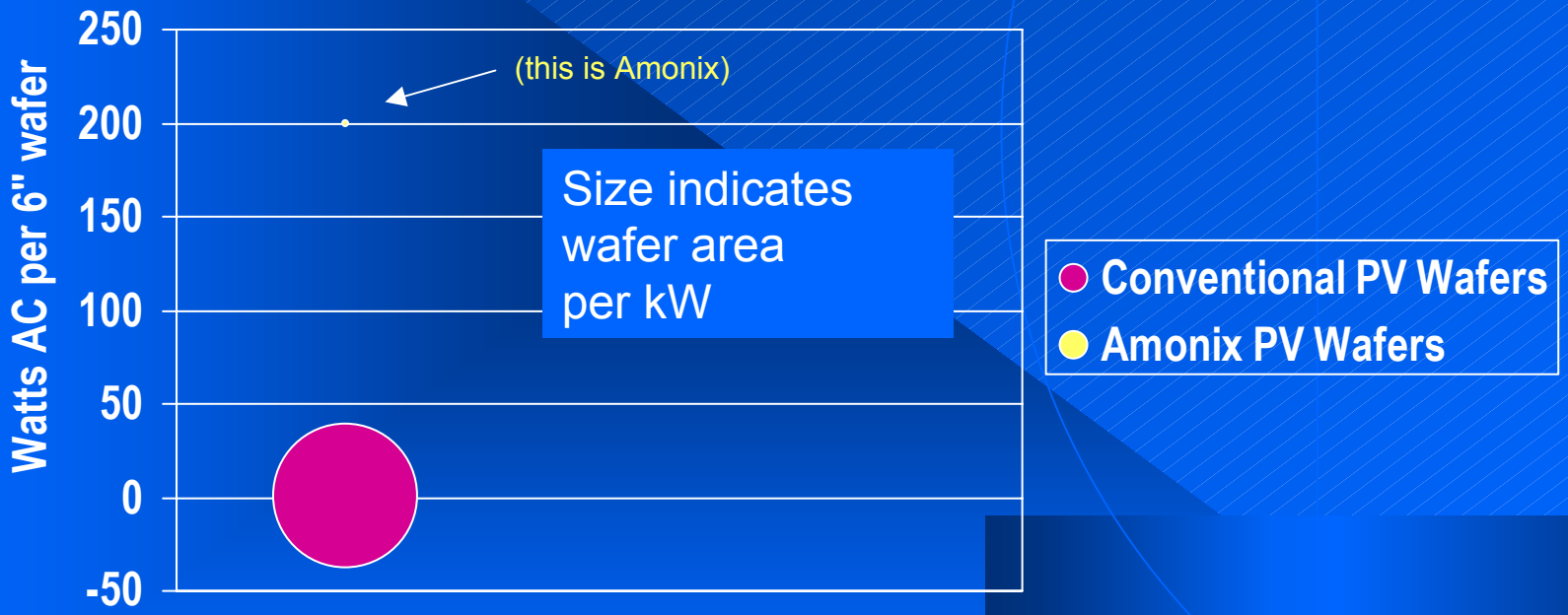
Emerging technologies have lower cost potential, in volume.

First Near-Commercial HCPV Systems

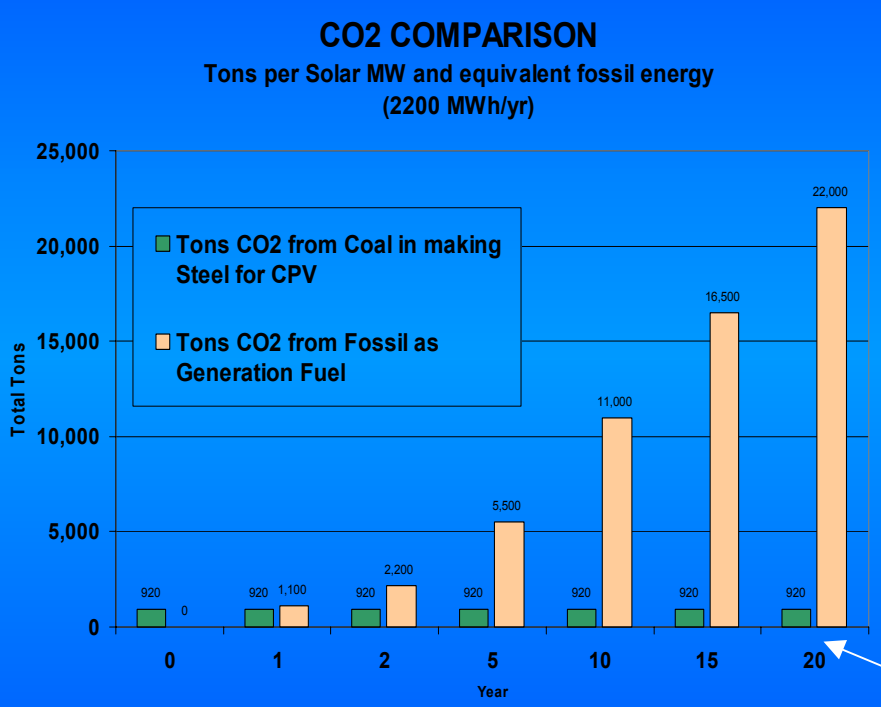
- Joint development with Amonix Inc., of Torrance CA
  - 25% silicon cell efficiency
  - 500 kW ac being demonstrated in field
  - new installation next year for NREL at UNLV

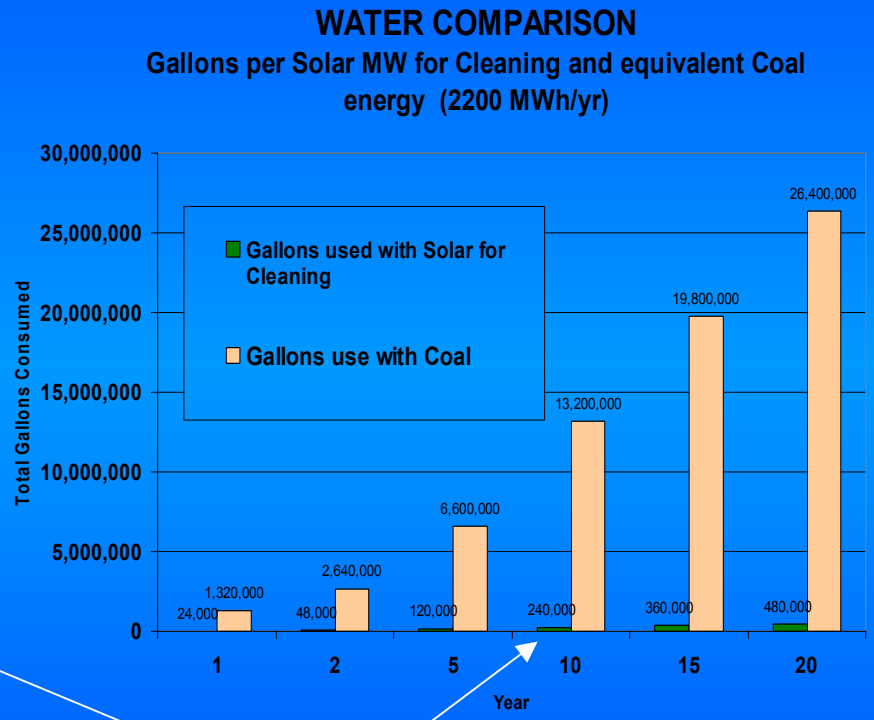
Time for Video!!

High Concentration Uses Very Little Semiconductor Wafer



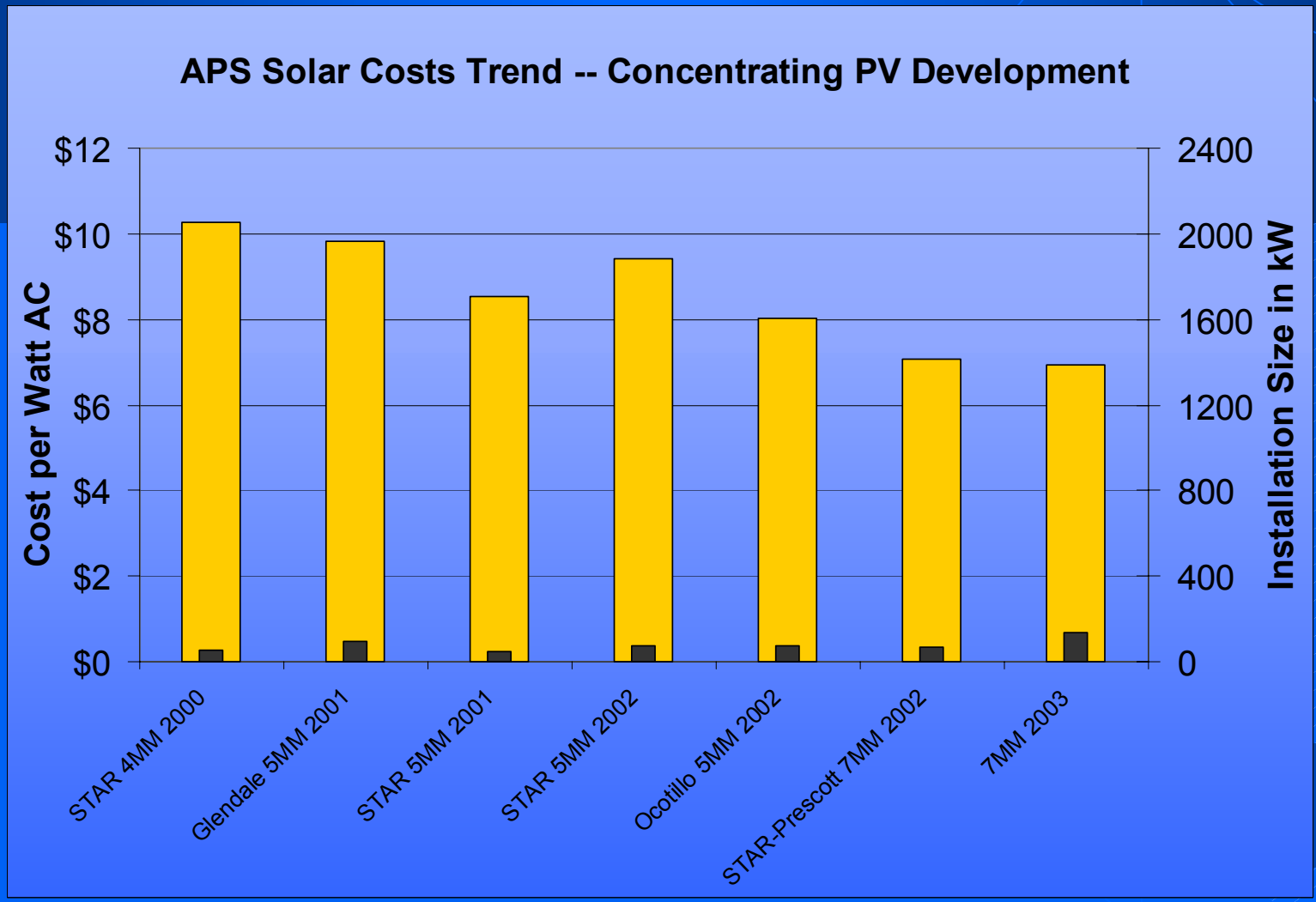
CO2 and Water Use Comparison of Solar Concentrators vs. Coal





Very substantial savings from solar

APS PV Concentrator -- System Cost Trends



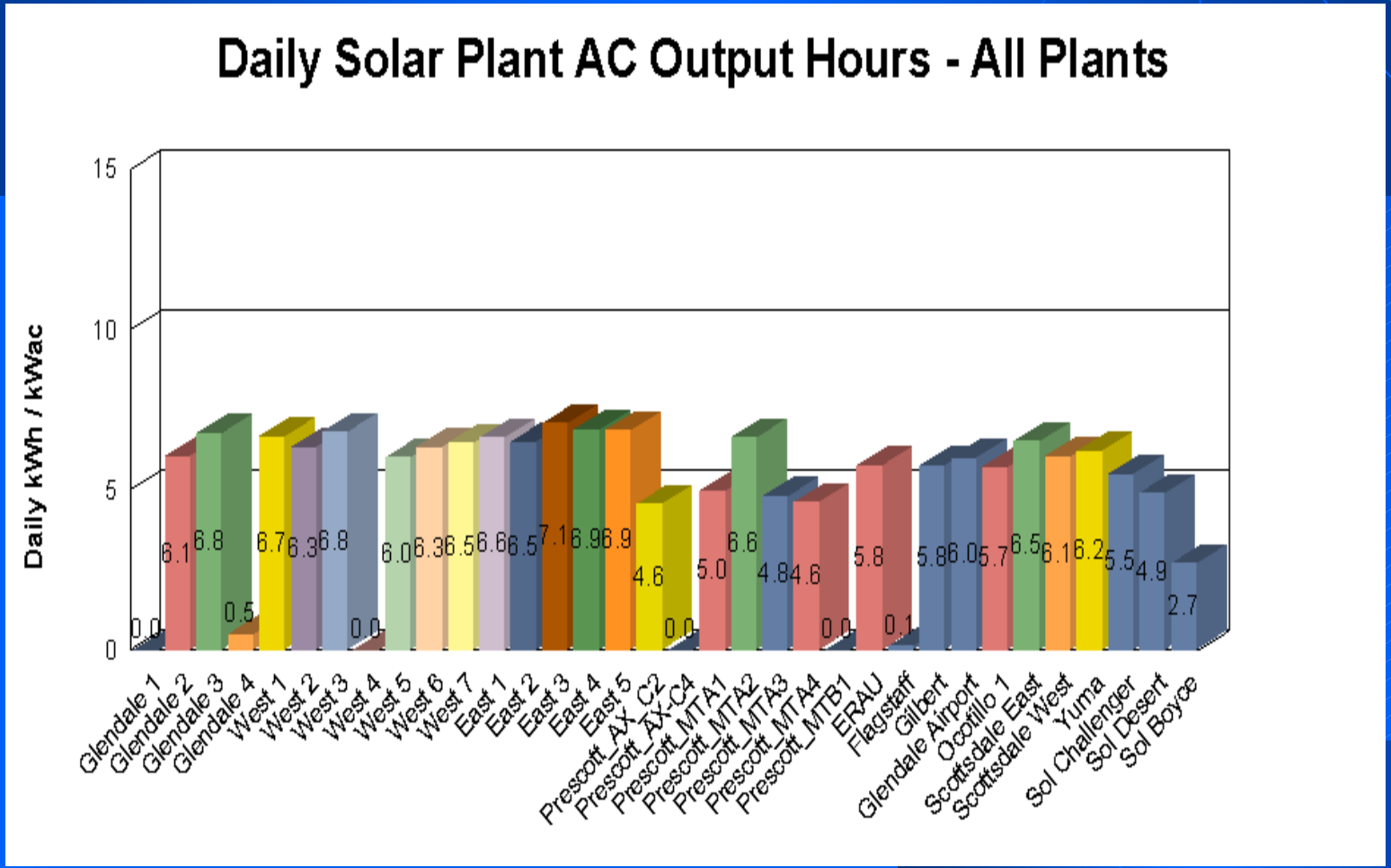
APS Solar Installations

- Over 4.5 MW total PV as of 2003
  - adding 1 to 2 MW per year
  - 5 MW solar plant being constructed near Prescott Airport
  - starting 1 MW solar trough plant
  - continuing CPV and dish engine development

Compare with regional goals:

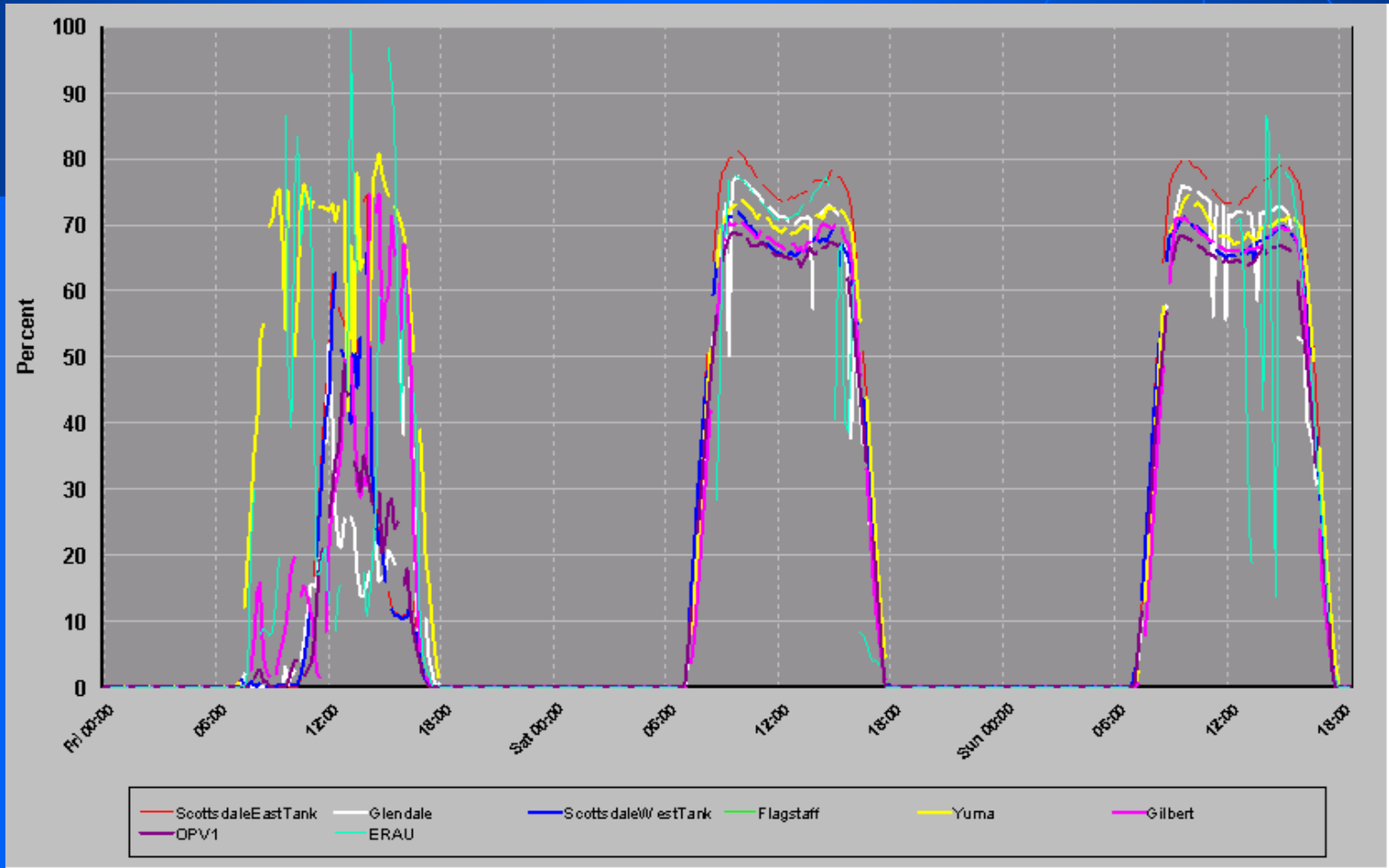
- 1% renewables per year would take over 500 MW / year
- over $1B each year if at competitive prices
- major cost reductions are essential for this to happen

Example APS PV Output Data -- 10/12/03

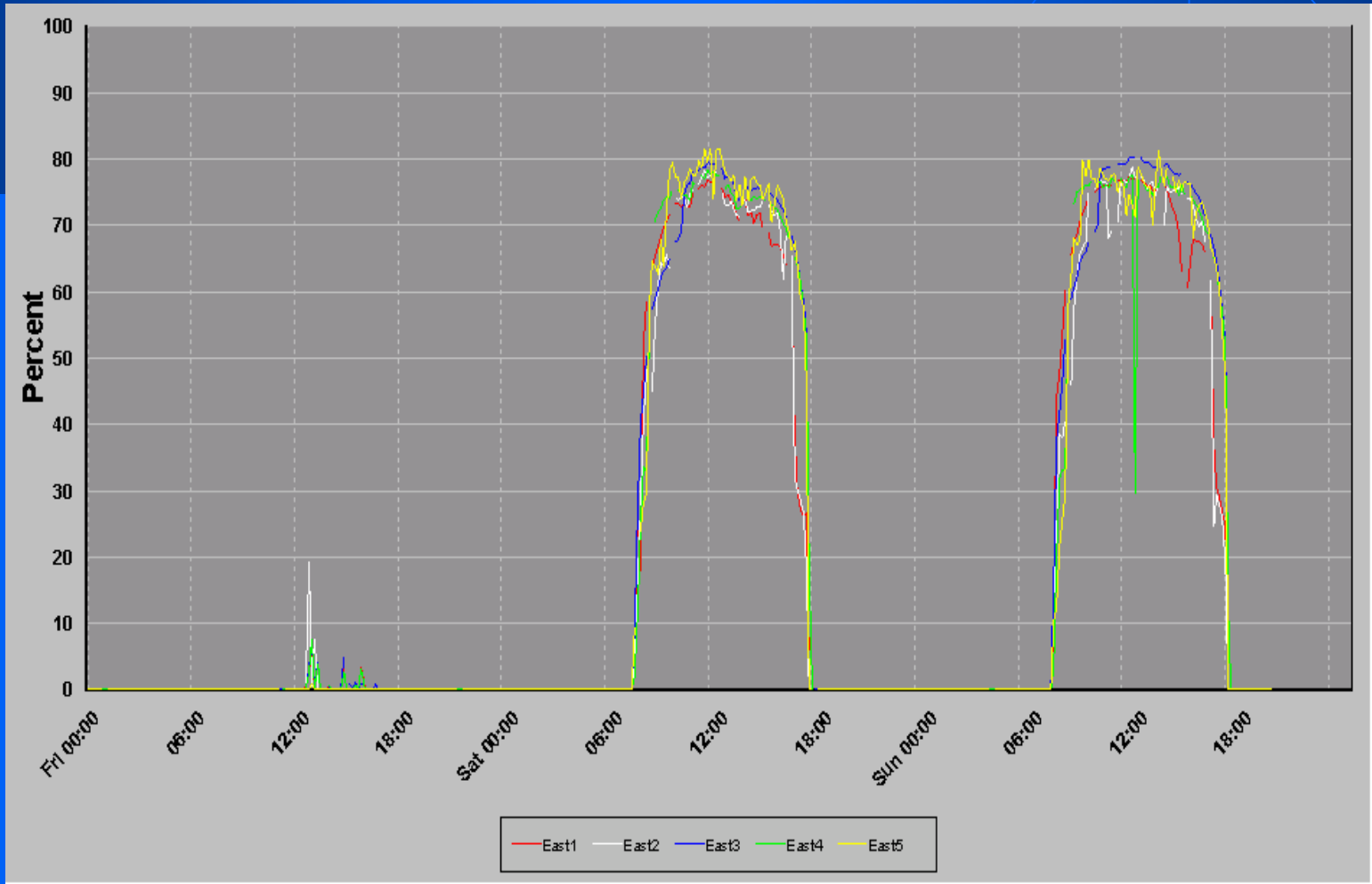


APS solar data-acquisition network, using digital AC meter readings

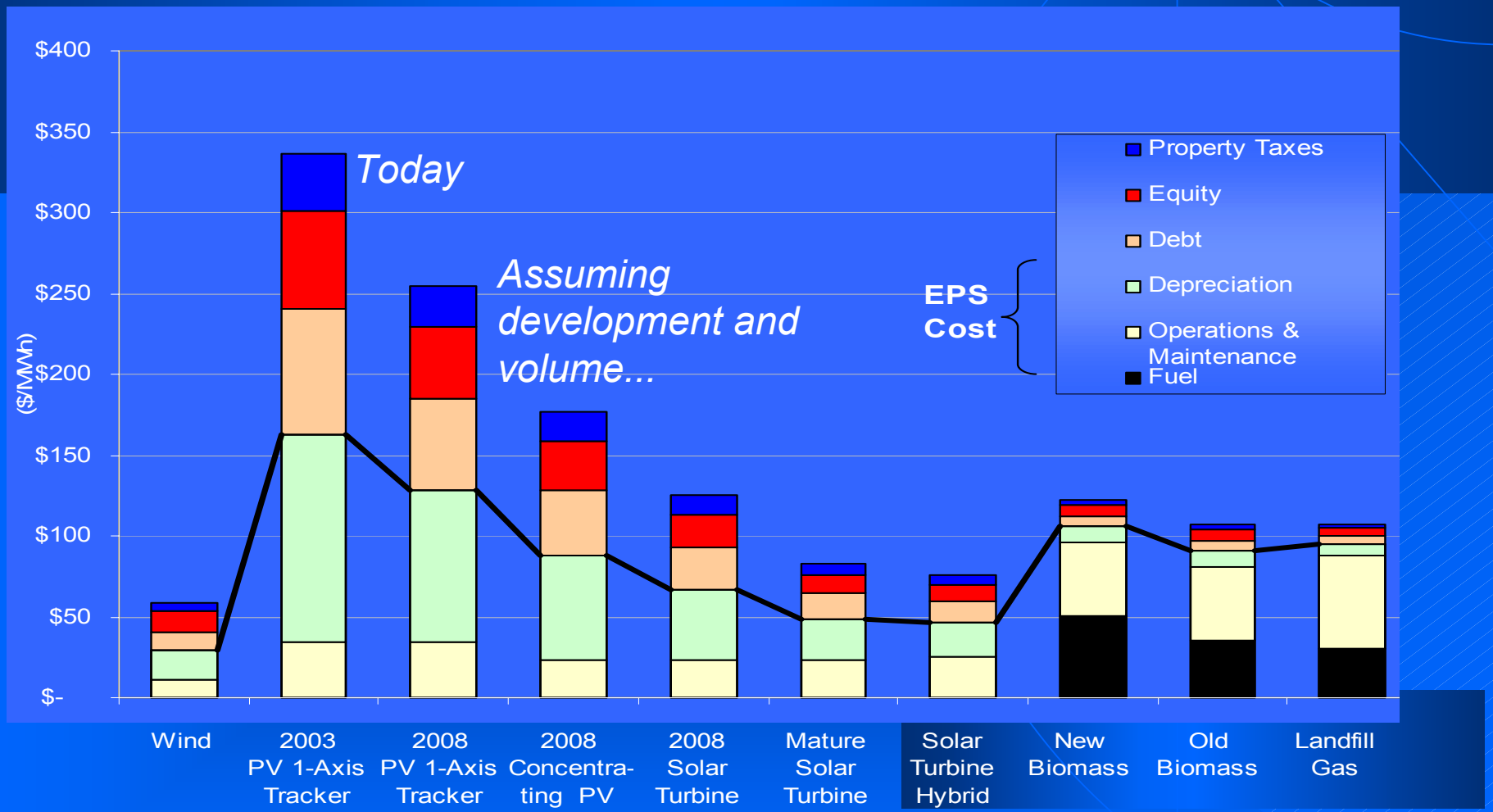
Example APS Single-Axis Data -- 10/10-12



Example APS HCPV Data -- 10/10-12



Cost Projections



Existing Generation

- Turbine engines
- Hydropower facilities
- Extraction industries
- Nuclear power

Each of these has required major, sustained public support.

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Public Policy and Business Climate

- Buy-downs vs. supply-side
  - cost and customer behavior are favored by supply-side
  - large utility projects provide opportunity for cost reductions and innovation
- Fuel prices, taxes and financing
  - these have very large impact on solar competitiveness
  - low interest rates and low taxes are enablers
  - but the gap is still too large for commercial ventures

Sustained development is needed to bridge the gap between RPS and emerging, lower cost technologies.

Increasing Federal Support is Critical

- new technologies require sustained development
- APS has long term working relationships with labs, reflected by:
  - CRADA with US Army Yuma Proving Ground for solar
  - two new MOUs with NREL, for CPV and trough
  - new CRADA with Sandia for Dish and system studies
  - work with Weizmann Institute of Science and others

Utility RPS requirements, and the potential of new solar technologies, are a true leveraging opportunity.

Current Technical Hurdles

- Market -- both utilities and IPPs -- are not interested in large scale risks, but they are the large market
- Green market is not sufficient -- low cost and system value are essential for large scale use
- Technical support and market demonstrations -- similar to wind industry -- are needed for medium scale CSP, to help open the door for larger scale.

Additional technical demonstrations, and credible studies of economic and environmental impacts are needed.

Going Forward

- APS continues to support the development of renewables with particular support of solar
- Concentrating solar, both CPV and thermal, can rapidly bypass cost/value of conventional PV
- Gap between RPS and lower cost technologies can be closed with adequate R&D support

Success will mean substantial use of solar, with environmental, economic, and resource benefits.


APS Prescott Airport
5 MW Solar Project